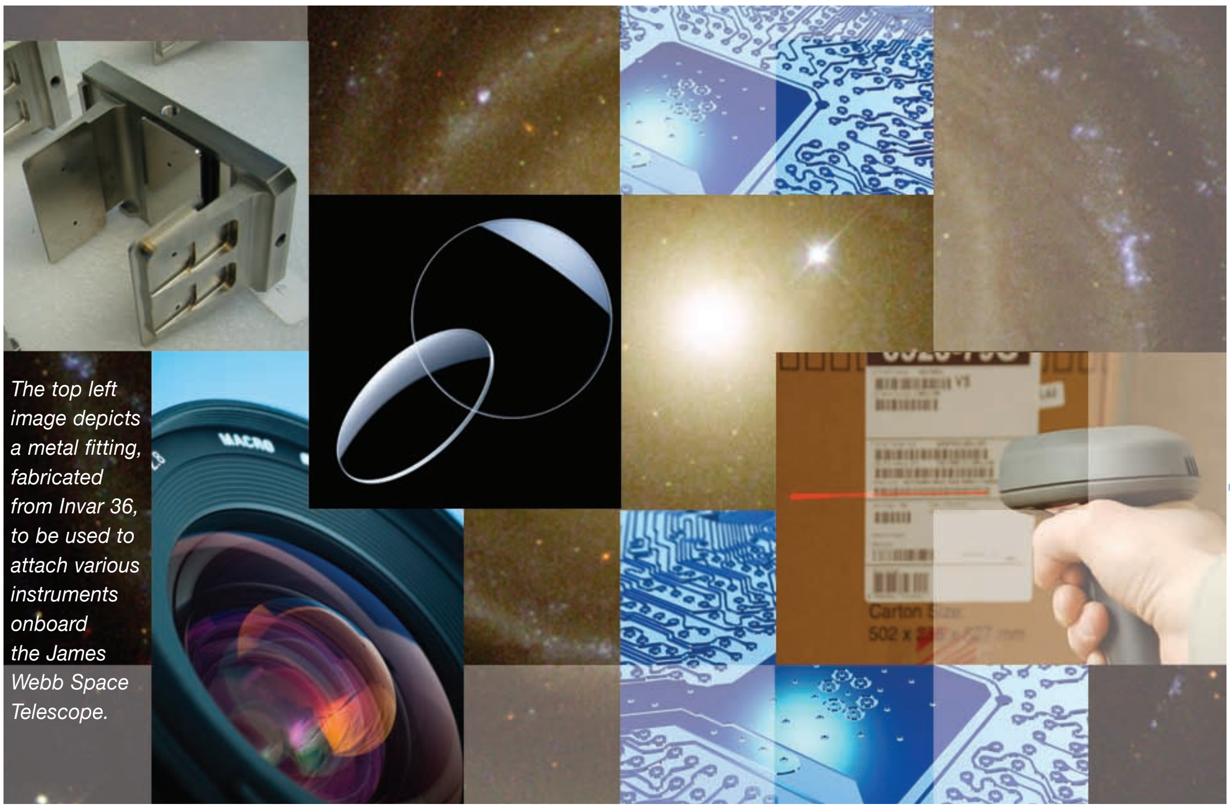
National Aeronautics and Space Administration

optics

Nanophase Dispersion Strengthened Invar 36

Conceptual method offers a stronger, more useful Invar 36



The top left image depicts a metal fitting, fabricated from Invar 36, to be used to attach various instruments onboard the James Webb Space Telescope.

NASA Goddard researchers have developed a conceptual method for strengthening Invar® 36, a nickel-iron alloy featuring a very low coefficient of thermal expansion (CTE). While Invar 36 features high dimensional stability, it suffers from low strength, high density, and low specific stiffness—all of which limit its usefulness. Goddard's method uses a nanoscale material as a reinforcing phase to form a metal matrix composite offering a stronger, lighter, and stiffer material while still maintaining the very low thermal expansion characteristic of Invar 36. This is important because it allows the metal matrix composite to resist deformation under loading and remain dimensionally stable during extreme temperature changes.

Benefits

- **Very low CTE**: Maintains dimensions and shape despite temperature variation
- **Microstructurally Stable**: Will not undergo phase transformation at cryogenic temperatures offering greater dimensional stability
- **Lower density**: Reduces mass, resulting in lighter structures
- **Increased strength and creep resistance**: Reduces section thickness for a given loading configuration compared with conventional Invar 36

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Applications

Potential applications for this concept method include:

- Mounting and support structures for satellite-based optics and precision sensors
- High quality telescopes, binoculars, cameras, lasers, and optical sights
- Laser rangefinders and other surveying equipment
- Metrology equipment
- Precision instruments such as optical benches, optical metering components, and support structures
- Support structures for laser-based opto-electronics used in spectrometry
- Mandrels, molds, and tooling where precision is required
- Precise mechanical clocks and scientific instruments
- Resonant cavities for VHF/UHF and microwave components
- Shadow masks for photo-lithography

Technology Details

How it works

Invented in 1896 by Swiss physicist Charles Edouard Guillaume, Invar is an iron-nickel alloy with a uniquely low CTE. Guillaume received the Nobel Prize in physics in 1920 for this discovery, demonstrating its importance in scientific instruments. Despite this importance, Invar 36 is a solid solution that cannot be strengthened through heat treatment and therefore suffers from low strength. In addition, its high density results in low specific stiffness. These characteristics make structures heavy and necessarily result in a mass penalty when incorporated in space-flight designs. Despite these shortcomings, it is often used in satellite structures due to its low CTE, enabling structural stability despite temperature fluctuations such as those seen in space environments. Goddard's Nanophase Dispersion Strengthened Invar 36 addresses the shortcomings of the traditional Invar 36 by employing a metal matrix, which is reinforced with an inert, nanoscale dispersant. The dispersant acts as a reinforcing phase through Orowan strengthening, a phenomenon that results in dispersion hardened metals having a high rate of strain hardening. The dispersant is synthesized separately and then introduced into the iron-nickel matrix during a secondary process such as powder metallurgy. The resulting metal-matrix composite (MMC) retains the unique thermal expansion and stability properties of Invar 36 while also achieving lower density and higher specific stiffness with a 50% increase in yield strength measured at 0.2% offset.

Why it is better

Goddard's process differs from previous attempts to strengthen Invar 36 while maintaining its low CTE in several ways. For instance, prior attempts to form an in situ composite by introducing solutes such as Mo and C that later react and precipitate through heat treatment to form Mo2C, have met with limited success due to the finite solubility of the iron-nickel matrix and the extreme sensitivity of the thermal expansion properties on the presence of unreacted elements in solution. In addition, the use of high-purity iron and nickel starting materials in Goddard's process ensures optimum thermal expansion properties by minimizing the presence of contamination in the alloy, which could otherwise degrade thermal expansion properties. Finally, unlike other strengthening attempts, the composition of the dispersed phase in Goddard's process is chosen to minimize thermal expansion mismatch between the Invar 36 matrix and the individual particle, thus minimizing thermal stresses in the matrix over a wide range of temperature change.

This innovative process is capable of producing a unique, mass-saving, damage-tolerant, dimensionally stable aerospace structural material.

Patents

NASA Goddard is seeking patent protection for this technology. Invar® is a registered trademark of Imphy Alloys.

Licensing and Partnering Opportunities

This technology is part of NASA's Innovative Partnerships Program Office, which seeks to transfer technology into and out of NASA to benefit the space program and U.S. industry. NASA invites companies to consider licensing the Nanophase Dispersion Strengthened Invar 36 method (GSC-15158-1) for commercial applications.

For information and forms related to the technology licensing and partnering process, please visit the Licensing and Partnering page.

For More Information

If you are interested in more information or want to pursue transfer of this technology (GSC-15158-1), please contact:

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